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Simulated Annealing to solve single stage capacitated warehouse location problem

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Abstract

Facility Location Problem (FLP) is a critical aspect in supply chain that is difficult to be solved in order to design an efficient supply chain. The terms of location problem refers to modeling, formulating, and solving problem, which is determining the location of facilities in certain area. Warehouse Location Problem is one model of Facility Location Problem which aims to locate the set of warehouses as one of distribution facility. In this study, a mathematical model of Single Stage Capacitated Warehouse Location Problem (SSCWLP) has been developed to determine the optimal warehouse location in fertilizer distribution of PT. Petrokimia Gresik in Sumatera Island, Indonesia. Basically, SSCWLP is an NP-Hard problem that requires long computing time to be solved by using exact methods. The weakness is resolved by using metaheuristics algorithm, namely Simulated Annealing (SA). The next step is testing the performance of SA by comparing the results of SA with those of branch & bound (BB). The algorithm provides results which are better to the existing solutions and have small gaps with those of exact method.

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Keywords: Capacitated Warehouse location problem, Simulated Annealing, Metaheuristics

1. Introduction

Nowadays the role of supply chain management in the company has become more strategic, especially by the company that has wide coverage product. Through supply chain management, the process of fulfilling customer demand will be more effective and efficient. To reach a responsive and efficient supply chain, a company has to notice four supply chain drivers, which are inventory, transportation, facility, and information. [3]

Facility location is a critical aspect in the supply chain and has a crucial role in logistic operation. In order to improve effectiveness and efficiency in meeting the customer demand, facility location will determine the lead time and transportation cost. The aims of facility location is to find the best facility location and demand

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allocation for each distribution facility. Location routing problem is classified into four categories: analityc, continuous, network, and discrete models [9]. Analityc model is based on a large number of simplifying assumptions such as the fixed cost of locating facility and the travel distances follow the Manhattan metric. Continuous model deals with geometrical representations of reality, and is based on the continuity of location area. The networks model is composed of link and nodes. Distance is measured with respect to the shortest path. The last is discrete model. In this model, there are discrete set of candidate locations that a facility can be located.

Studies have been conducted to reveal the complexity of Facility Location Problem (FLP). Models and algorithms development have been formulated to solve problem in this field, such as gravity method and mixed integer linear programming method. One kind of FLP that is frequently studied is Uncapacitated Facility Location Problem (UFLP) or generally known as Simple Facility Location Problem (SFLP). Erlenkotter [5] developed dual-based algorithm to solve UFLP. The other generally used methods are branch and bound algorithm by Efroymson & Ray [4] and implicit enumeration technique by Spielberg [11]. To be more realistic, then capacity is included as a constraint, namely Capacitated Facility Location Problem (CFLP). The first heuristic method to solve CFLP had been developed by Kuehn & Hamburger [67]. Thereafter, Akinc and Khumawala developed branch and bound with linear programming relaxation [1] and Nauss [8} used Lagrangean relaxation to solve the problem [8]. Several effective methods to solve CFLP are cross-decomposition algorithm by Roy [10] and Lagrangean-based approach by Beasley [2]. Besides, there are other variants of FLP, namely P-Median Problem (PMP), P-Center Problem (PCP), Maximal Covering Location Problem (MCLP), and Hub Location Problem (HLP).

The other variant of FLP is Warehouse Location Problem (WLP). WLP had been developed to solve warehouse location planning. Align with FLP, WLP is a strategic aspect in logistic operation. Failure to find an optimal warehouse location will bring potential losses. One study conducted in WLP was Single Stage Capacitated Warehouse Location Problem (SSCWLP) which is also considering the location of plant from which the warehouse get the supply. This warehouse location will be more effective in planning a widely distributed product.

One case of widely distributed products is fertilizer. Indonesia as a well-known agricultural country, needs fertilizer to support their farming and gardening. To meet the customer demand across Indonesia is a complex problem. PT. Petrokimia Gresik as one of fertilizer producers owned by Indonesia government needs to build a good supply chain management to overcome this complex logistic problem. It certainly requires a well-planned warehouse location to support their logistic operation. its distribution system consists of four lines. The first line is the plant in Gresik. Second line is the warehouse which receives products from the first line. Third line is the warehouse which receives products from the second line. And, the fourth line is distributor. In this study, the fourth line is assumed as customer to confirm the warehouse location will be effective to the end customer.

Location problem in PT. Petrokimia Gresik is considered as SSCWLP. In this case, we consider warehouses in the second line to determine the location of third line warehouses. Both FLP and WLP are categorized as NP-hard problems which are difficult to be solved by exact optimization methods. By using exact methods, usually it will take a long computation time to get the optimal results. Studies have been conducted to minimize the lack and metaheuristics rises as the answer. Metaheuristics yields good solutions with shorter computation time. Some metaheuristics algorithm frequently used in solving FLP are Tabu Search (TS), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Simmulated Annealing (SA) and Scatter Search (SS).

This paper is organized as follows. The next section presents the literature review regarding with facility location problem, warehouse location problem and simulated annealing. In section 3 we discuss the mathematical formulation of the problem. Section four presents Simulated Annealing procedure to solve SSCWLP. Sections five discusses the experimental setting and the last section concludes the results.

2. Literature Review

Some literature review have been published for Warehouse Location Problem. In this study, there are three main literature of WLP used to develop model, which are Warehouse Location Problem with Fixed Installation Cost [1], Capacitated Warehouse Location Problem with Constraints in Customer being Serviced [7], and Single Stage

Capacitated Warehouse Location Problem [13].

2.1 Warehouse Location Problem with Fixed Installation Costs

Location problem in this model categorized as discrete model [1]. Capacity in each warehouse is assumed to be equal and infinite, transportation cost increase based on the order quantity, number of warehouse is not more than the candidate point, and customers have to be allocated into opened warehouse.

Parameters :

k : customers (k = 1, 2, …., q)

j : candidate points (j = 1, 2, …., n)

f_j : cost of opening warehouse j

r_k : customer's demand

v_{kj} : the cost of shipment to customer k from warehouse j for each unit

$c_{kj} = v_{kj} + r_k$

Decision Variabel :

x_{kj} : a fraction of r_k which is transported from j to customer k

y_i : Will be equal one if the candidate point j is selected, otherwise it will be equal to zero

Objective Function and Constraints :

$$\text{Min } Z = \sum_{j=1}^{n} f_i y_j + \sum_{j=1}^{n} \sum_{k=1}^{q} c_{kj} x_{kj} \quad (1)$$

s.t

$$\sum_{j=1}^{n} x_{kj} = 1; k = 1, \ldots, q \quad (2)$$

$$-x_{kj} + y_i \geq 0 \quad (3)$$

$$0 \leq x_{kj} \leq 1 \quad (4)$$

$$y_j \in \{0,1\} \quad (5)$$

Eq. (2) ensure all customer's demand fulfilled and maximum number of x_{kj} equal to 1. Eq. (3) ensures that a warehouse in point j serves customer k if a warehouse has been located in that point.

2.2 Capacitated Warehouse Location Problem with Constraints in Customer being Serviced

This model includes customer constraint **(Nagy, 2004)**. Each warehouse can serve only a limited number of customers and each customer must be supplied by exactly one opened warehouse. The objective is to determine which warehouses to open, and the allocation of the customers to the opened warehouses.

Parameters :

k : customers (k = 1, 2, …., q), j: candidate points (j = 1, 2, …., n)

f_j : cost of opening warehouse j , r_k: customer's demand

v_{kj} : the cost of shipment to customer k from warehouse j for each unit, $c_{kj} = v_{kj} + r_k$

Decision Variabel :

O_j : vector of Booleans indicating what warehouses have been opened

S_{kj} : matrix of Booleans indicating if customer k is supplied by warehouse j

Objective Function and Constraints :

$$\text{Min } \sum_{k,j} S_{kj} c_{kj} + c_f \sum_j O_j \quad \textbf{(6)}$$

s.t

$$\sum_j S_{kj} = 1, \ \forall k \quad \textbf{(7)}$$

$$\sum_k S_{kj} \le Capacity_j, \ \forall j \quad \textbf{(8)}$$

$$\sum_k S_{kj} \le O_j, \ \forall k, j \quad \textbf{(9)}$$

Eq. (7) ensures that customer can be supplied by only one warehouse. Eq. (8) ensures that each warehouse has fixed capacity and eq. (9) ensures that customer can be supplied by opened warehouse.

2.3 Single Stage Capacitated Warehouse Location Problem

SSCWLP does not only consider customer location, but also plant location to supply the warehouse in order to find the optimal warehouse location **[13]**.

Parameters :

i : plant , j : warehouse , k: market , D_k: demand for the commodity at market *k*
d_k : $D_k / \sum D_k$ demand at market *k* as a fraction of total market demand
S_i : supply available at plant *i* s_i : $S_i / \sum D_k$ supply available at plant *i* as a fraction of the total market demand
f_i : fixed cost of locating a warehouse at *j*, C_{ijk} : cost of transporting a quantity of goods from *i* to *j* to market *k*
CAP_j : capacity of warehouse *j*
cap_j : $CAP_j / \sum D_k$ capacity of the warehouse at location *j* as a fraction of The total market demand

Decision Variabel :

X_{ijk} : quantity of commodity transported from plant *i* to warehouse *j* to market *k*
x_{ijk} : $X_{ijk} / \sum D_k$ quantity transported as a fraction of total market demand
y_j : will be equal 1 if warehouse is located at location j; 0 otherwise

Objective Function and Constraints :

$$\text{Min } \sum_i \sum_j \sum_k c_{ijk} * x_{ijk} + \sum_j f_j * y_j \quad \textbf{(10)}$$

s.t

$$\sum_i \sum_j \sum_k x_{ijk} = 1 \quad \textbf{(11)}$$

$$\sum_j \sum_k x_{ijk} \le s_i, \ \forall i \quad \textbf{(12)}$$

$$\sum_i \sum_j x_{ijk} \ge d_k, \ \forall k \quad \textbf{(13)}$$

$$\sum_i \sum_k x_{ijk} \le cap_j, \ \forall j \quad \textbf{(14)}$$

$$x_{ijk} \ge 0, \ \forall i, j, k \quad \textbf{(15)}$$

Eq. (11) ensures that the flow through the entire network is equal to the total demand of all market. Eq. (12) ensures that the outflow from a supply point is less than its supply. Eq. (13) ensures that the inflow at a market point meets the demand of that point. Eq. (14) is warehouse capacity constraints and eq. (15) is non-negativity constraint. Below are the constraints that link the real and binary variable.

$$\sum_i \sum_k x_{ijk} \leq cap_j \, y_j, \ \forall j \tag{16}$$

$$\sum_i \sum_k x_{ijk} \leq y_j, \ \forall j \tag{17}$$

$$\sum_i x_{ijk} \leq d_k y_j, \ \forall j \tag{18}$$

$$\sum_k x_{ijk} \leq s_i y_j, \ \forall i, j \tag{19}$$

$$\begin{aligned} &\sum_i \sum_k x_{ijk} + M\,(1 - y_j) \geq 0, \ \forall j \\ &\sum_i \sum_k x_{ijk} + M\, y_j \geq 0, \ \forall j \\ &\sum_i \sum_k x_{ijk} - M\, y_j \geq 0, \ \forall j \end{aligned} \tag{20}$$

$$\begin{aligned} &\sum_i x_{ijk} - M\left(1 - y_j\right) \leq d_k, \ \forall j, k \\ &\sum_i x_{ijk} + M y_j \geq 0, \ \forall j, k \\ &\sum_i x_{ijk} - M y_j \geq 0, \ \forall j, k \end{aligned} \tag{21}$$

$$\begin{aligned} &\sum_k x_{ijk} - M(1 - y_j) \leq s_i, \ \forall j, i \\ &\sum_k x_{ijk} + M y_j \geq 0, \ \forall j, i \\ &\sum_k x_{ijk} - M y_j \leq 0, \ \forall j, i \end{aligned} \tag{22}$$

$$y_j = [0,1], \ \forall j \tag{23}$$

$$y_j \geq 0, \ \forall j \tag{24}$$

2.4 Simulated Annealing

Simulated Annealing (SA) is one of metaheuristic algorithm adapted from metal annealing process. SA is selected as it is simple, easy to implement and it has specific feature to get out form the trap of local optma. The feature is called Metropolis criterion, where a worse solution may be accepeted is the next solution with certain probability. By accepting worse solution it is expected that in the other next we can mve to the better solution compared to previous solutions.

SA imitate the process of metal annealing. Once the metal is heated, the atoms in that steel will move freely, and the movement will be more limited in line with the decreasing in temperature. When the temperature decrease, the arrangement of the atoms will become more regular, and eventually form crystals that have minimum internal energy [12].

The adaptation of the annealing process is applied in SA algorithm with adding a parameter similar to the temperature and control it with the concept of the Boltzmann probability distribution, which is represented by the following formula : $P(E) = e^{-E/kT}$, where $P(E) =$ probability to reach energy level E, T =temperature, $k =$ Bolztmann constants. The equation indicates that the lower the temperature, the less probability to reach high energy of E, so that the searching process will be more convergent.

3. Single Stage Capacitated Warehouse Location Problem in PT Petrokimia Gresik

Warehouse Location Problem at PT. Petrokimia Gresik is limited in the decision of opening third line warehouse with respect to the location of second line warehouse and customer. Second line warehouse is assumed as plant which supplies product to third line warehouse. Second line and third line warehouses can serve directly to customers. This study takes a problem of SSCWLP of fertilizer distribution in Sumatera Island. There is 10 second line warehouse available, 30 third line warehouse to decide, and 151 customer location need to be served.

There is also a customer constraints where the customer can be served by only one warehouse, either second line warehouse or third line warehouse. Below is the mathematical model developed to solve SSCWLP in PT. Petrokimia Gresik.

Parameters :

D_k : demand at location k S_i : supply from second line warehouse

f_j : fixed cost of opening third line cap_j : third line warehouse

cpw_{ij} : transportation cost from second line warehouse to third line warehouse

cpm_{ik} : transportation cost from second line warehouse to demand

cwm_{jk} : transportation cost from third line warehouse to demand

Decision Variable :

xpw_{ij} : product allocation from second line warehouse to third line warehouse

xpm_{ik} : product allocation from second line warehouse to demand

xwm_{jk} : product allocation from third line warehouse to demand

$y_j \begin{cases} 1, & \text{if third line warehouse } j \text{ is opened} \\ 0, & \text{if not} \end{cases}$

$zpm_{ik} \begin{cases} 1, & \text{if second line warehouse } i \text{ serves demand } k \\ 0, & \text{if not} \end{cases}$

$zwm_{ik} \begin{cases} 1, \text{if third line warehouse } j \text{ serves demand } k \\ 0, \text{if not} \end{cases}$

Objective Function and Constraints :

$$\textbf{Min } \sum_i \sum_j \boldsymbol{cpw_{ij} xpw_{ij}} + \sum_j \sum_k \boldsymbol{cwm_{jk}\, xwm_{jk}} + \sum_i \sum_k \boldsymbol{cpm_{ik} xpm_{ik}} + \sum_j \boldsymbol{f_j y_j} + \sum_j \sum_k \boldsymbol{cbm_{jk} xwm_{jk}} \quad (25)$$

s.t

$\sum_j \boldsymbol{xpw_{ij}} + \sum_k \boldsymbol{xpm_{ik}} \le \boldsymbol{S_i} \ \forall \boldsymbol{i}$ (26) $\sum_i \boldsymbol{xpm_{ik}} + \sum_j \boldsymbol{xwm_{jk}} \ge \boldsymbol{D_k} \ \forall \boldsymbol{k}$ (27)

$\sum_i \boldsymbol{xpw_{ij}} \le \boldsymbol{y_j cap_j} \ \forall \boldsymbol{j}$ (28) $\sum_i \boldsymbol{xwm_{jk}} \le \boldsymbol{y_j cap_j} \ \forall \boldsymbol{j}$ (29)

$\sum_i xpw_{ij} = \sum_k xwm_{jk} \ \forall j$ (30) $\sum_i zpm_{ik} + \sum_j zwm_{jk} = 1 \ \forall k$ (**Error! No text of specified style in document.**1)

$xpm_{ik} \le S_i zpm_{ik} \ \forall i, k$ (32) $xwm_{jk} \le cap_j zwm_{jk} \ \forall j, k$ (**Error! No text of specified style in document.**3)

$xpw_{ij} \ge 0$ (34) $xpm_{ik} \ge 0$ (35)

$xwm_{jk} \ge 0$ (36) $y_j \in \{0,1\}$ (37)

$zpm_{ik} \in \{0,1\}$ (38) $zwm_{jk} \in \{0,1\}$ (39)

Eq. (26) ensure that the total supply from second line warehouse does not exceed its supply capacity. Eq. (27) ensure demands have to be fulfilled. Eq. (28) is a capacity constraints of third line warehouse to store supply from second line warehouse. Eq. (29) is a capacity constraints of third line warehouse to supply customer demand. Both eq. (28) and eq. (29) ensure the closed third line warehouse will not either store the supply from second line warehouse or supply to customer. Eq. (30) ensure no inventory in third line warehouse. Eq. (31) is a customer constraint that a customer can only be served by one warehouse, either second line warehouse or third line warehouse. Eq. (32) and eq. (33) link the product supply with binary variable *z*. Eq. (34) to eq. (36) is a non-negativity constraints. Eq. (37) to eq. (39) are binary variables.

3. Simulated Annealing Procedure

The proposed SA procedure is applied to solve SSCWLP in PT. Petrokimia Gresik. The followig is the steps how SA was applied.

1. Parameters Definition

SA has initial parameters to control the searching process. Those are initial temperature (T_0), temperatur reduction factor (C), and number of cycle (n). These parameters are tested to get the best combination and find the best result.

2. Generating Initial Solution (x_0)

Initial solution is generated randomly by using permutation random. The initial solution consist of the sequence of each second line warehouse (x1), third line warehouse (x2), and customer (x3).

Table. 1 Initial Solution

X1	1	2		
X2	1	2	3	
X3	4	3	1	2

After generating the initial solution, the next step is to generate the solution structure of second line warehouse and customer.

Table. 2 Solution Structure of Second Line Warehouse and Customer

1	3	3	1	3	3
1	4	3	2	1	2
40	12	22	40	15	17

The solution structure in Table.2 is generated by placing the sequence of x1 in Table.1 in a new solution structure. Then x3 is inserted in that new solution. The first line of Table.2 is an index. Number 1 indicates the second line warehouse, 2 is third line warehouse, and 3 is customer. Line two is the sequence for each warehouse and customer. Line three shows the supply capacity of warehouse and demand for each customer. The following step is inserting the sequence of x2 randomly to the solution structure of second line warehouse and customer and result in the solution structure of SA SSCWLP as shown in Table. 3.

Table. 3 Solution Structure of SA SSCWLP

1	2	3	2	2	3	1	3	3
1	1	4	2	3	3	2	1	2
40	39	12	35	31	22	40	15	17

3. Warehouse Allocation

The next step is to check whether the solution structure of SA SSCWLP follows the capacity constraints or not. If the demands exceed the warehouse capacity, then the customer will be assigned to the other third line warehouse or second line warehouse. The closed third line warehouses will be deleted in this step. The closed third line warehouse in this example is warehouse number 2. Product allocations are calculated after fixing the solution structure. The allocation example is shown in Table.4 below. P indicates second line warehouse, L indicates third line warehouse, and D indicates customer. The following number indicates the order.

Table. 4 Warehouse Allocation

	P1	P2	P3	D1	D2	D3	D4
L1	12	0	22	0	0	0	0
L2	0	0	0	15	17	0	0
P1	0	0	0	0	0	0	12

P2	0	0	0	0	0	0	0
P3	0	0	0	0	0	22	0

4. Objective Function
Objective function of SSCWLP consist of transportation and fixed costs of opening third line warehouse. Transportation cost is calculated by multiply product allocation in Table 4 with distance matrix and transportation cost per ton km.
5. Generating New Solution
Generating new solution is done by generating new solution for second line warehouse and also for combination of third line warehouse and customer. These are done by using flip, swap, or slide to get new solution from the previous one. The first step is to do flip, swap, or slide to the solution structure of third line warehouse and customer. Flip, swap, or slide are also applied to the solution structure of second line warehouse. Then, the new solution structure of second line warehouse is inserted to the solution structure of third line warehouse and customer.
6. Solution Comparison
Total cost for each new solution and the previous solution are compared. If the new solution is less than the previous one, new solution is accepted and will be used for the next iteration. If not, then the new solution is considered by Metropolis criteria.
7. Iteration, Cycle, and Temperature Update
Iteration and cycle update are done after getting the new solution. Whereas temperature update is done after the cycle reach maximum number of cycle (n).
8. Stopping Criteria
This SA SSCWLP uses maximum number of iteration as a stopping criteria.

1. Experiment

The experiments of SA SSCWLP consist of three steps. First, experiments were performed with existing condition of SSCWLP in PT. Petrokimia Gresik. Second, experiments were done by using exact method (Branch & Bound) implemented in LINGO. Third, experiments were performed by using SA. The total cost of each condition is compared to see the performance of SA. The existing condition is SSCWLP in Sumatera Island which consist of 10 second line warehouses, 30 third line warehouses, and 151 customer locations. The other data sets used in the experiment are the distance among warehouses, distance from warehouses to customer locations, rental cost of warehouses, cost of labor, loading-unloading cost and demand for each customer. Special for SA, first we had to tune the parameters values before running other experiments. From the experiments we got the following results

1. The calculation of existing condition with 30 warehouses, produces total cost of Rp 1,732,936,874.00, consist of transportation cost Rp 1,352,447,059.00 and rental cost of warehouse Rp 380,489,815.00.
2. The exact method recommends to open 3 out of 30 third line warehouses which are Tanah Karo, Solok, and Padimas warehouses with total cost result is Rp 924,840,000.00. The computation time is 3 hours 10 minutes.
3. The SA method experiments obtain the best parameters for SA were : 0.4 (temperature reduction factor, C), 15 (number of cyle, N) and 5000 (initial temperature, T). Those best combination parameters result was opening 11 out of 30 third line warehouses which are Dairi, Tanah Karo, Serdang Berdagai, Labuhanbatu, Padang Sidempuan, Solok, Batusangkar, Pasaman Barat, Bukit Tinggi, Pringsewu, Padimas warehouses. The best total cost is Rp 1,043,700,000.00 and best computation time is 10.2493 seconds.
4. There is -11% gap between SA's best cost with the exact method and 40% gap with the existing. The average computation time of best parameter experiments is 9.7813 seconds.

2. Conclusion

The proposed SA works well to solve SSCWLP and produced solutions which have small gap with those of the exact method. The solutions are also better than the existing ones. Although there is still 11% gap to the exact method, SA SSCWLP provides benefit in computation time. The results show the improvement of the SSCWLP in PT. Petrokimia Gresik with respect to the cost. The best parameters combination are c 0.4, n 15, and T_0 5000. These parameters combination will be different depend on the problem scale. The opened third line warehouse in Sumatera Island needs further feasibility studies to be applied. These studies include the letter of agreement review between distributor and others third party which are related to the logistic operation. Future research may apply the other metaheuristics algorithm to compare the performance of SA SSCWLP. Applying the SA SSCWLP in bigger problem scale is suggested to know the sensitivity of this algorithm.

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Reference

[1] Akinc, U. & Khumawala, B. M., 1977. “An Efficient Branch and Bound Algorithm for The Capacitated Warehouse Location Problem”, *Management Science,* pp. 585-594.
[2] Beasley, J. E., “An Algorithm for Solving Large Capacitated Warehouse Location Problems”., *Operation Research,* 1998, pp. 314-325.
[3] Chopra, S. & Meindl, P., *Supply Chain Management : Strategy, Planning, and Operation.* New Jersey: Prentice Hall, 2001.
[4] Efroymson, M. A. & Ray, T. L., “A branch and bound algorithm for plant location”, *Operation Research,*1966, pp. 361-368.
[5] Erlenkotter, D., “A dual-based procedure for uncapacitated facility location”, *Operation Research,* 1978,pp. 992-1009.
[6] Kuehn, A. A. & Hamburger, M. J., 1963. “A Heuristic Program for Locating Warehouses “, *Management Science,* 1963, pp. 643-666.
[7] Nagy, T., 2004. *Constraint Programming.* [Online] ,Available at: http://www.freehackers.org
[8] Nauss, R. M., “An Improved Algorithm for The Capacitated Facility Location Problem”. *Operational Research Society,* 1978, pp. 1195-1201.
[9] Ogryczak, W., Inequality measures and equitable approaches to location problems. *European Journal of Operational Research,*2000, pp. 374-391.
[10] Roy, T. V.,. A Cross Decomposition Algorithm for Capacitated Facility Location. *Operation Research,*1986, pp. 145-163.
[11] Spielberg, K., Algorithms for The Simple Plant Location Problem With Some Side Constraints. *Operation Research,* 1969, pp. 85-111.
[12] Santosa, Budi and Willy, Paul, Metoda Metaheuristik, Konsep dan Implementasi, Guna Widya, Surabaya, Indonesia, 2011
[13] Verma, P. & Sharma, R. R. K., “Vertical Decomposition Approach to Solve Single Stage Capacitated Warehouse Location Problem”. *American Journal of Operations Research,* 2011, pp. 100-117.